RADIUM

A MONTHLY JOURNAL DEVOTED TO THE CHEMISTRY, PHYSICS AND THERAPEUTICS OF RADIUM AND OTHER RADIO-ACTIVE SUBSTANCES

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PUBLISHED BY THE RADIUM PUBLISHING COMPANY
FORBES AND MEYRAN AVENUES, PITTSBURGH, PA.

We shall be glad to receive for publication from our subscribers and readers articles pertaining to the subject of radium and its application. All inquiries for information will be accorded prompt attention, and will be answered either by letter or through the columns of this paper.

VOL. II | OCTOBER, 1913 | No. 1

RADIUM AND MESOTHORIUM IN THE TREATMENT OF MALIGNANT TUMORS. I.

By OTTO SCHINDLER, M. D. (*Vienna*).

The splendid results which *Kronig, Bumm* and *Doderlein* were able to obtain in the treatment of uterus cancer by using large doses of filtered Rontgen and mesothorium gamma rays, as reported at the Gynecological Congress in Halle, have justly attracted the attention of the whole medical world. Stimulated by a several months sojourn in 1907-8 at the Paris Radium Institute of Doctors *Wickham* and *Degrais,* I have been working with radium in the treatment of malignant tumors for the past four years and with mesothorium for the past year. As I have had opportunity to treat a comparatively large number of cases in this time, it now seems desirable to give a report of results, especially since I have worked with sufficient quantities of both radium and mesothorium, and can make a comparison of their effects.

As regards the physical side, I will assume that the properties of the gamma rays of radium are known, and will only mention that commercial preparations of mesothorium vary considerably in composition and in radiating power. It has been said that 25% of the gamma ray activity of mesothorium is due to radium, but Prof. Stefan *Meyer* found that an Austrian mesothorium contained only between 2 to 4 per cent. of radium. The activity of mesothorium varies with time, increasing because of the formation of radiothorium and its products. The ratios of the activities due to the different forms of rays vary because of the formation of these new products. While pure mesothorium gives no alpha rays, the alpha ray activity slowly increases due to the formation of radiothorium and its subsequent products. To this will also be added the considrable alpha ray activity of the radium and its decay products present in the mesothorium. As regards the beta rays of mesothorium, it may be said that these are somewhat less penetrating than those of radium, and they show a somewhat different absorption curve from that of the radium beta rays. The gamma rays of mesothorium are about equally as penetrating as those of radium. Some workers have said that gamma rays of thorium D have about 10% greater penetrating

power than the gamma rays of radium C* however, this is not entirely certain (private communication from Prof. Stefan *Meyer*). In any event, the difference in penetrating power of the gamma rays of radium and mesothorium is so slight as to have no significance as far as the medical uses of these substances are concerned.

The hardest gamma rays of radium are far harder than the hardest X rays (Cf. the scheme of *Bayet* in *Lazarus*' Handbuch der Radium-Biologie und Therapie). The variations in activity and efficiency of mesothorium can possibly best be illustrated by the following measurements which Dr. *Paneth*, assistant in the Radium Research Institute of the Vienna Academy of Sciences has kindly made on my mesothorium preparation.

Activity measurements of Mesothorium Applicator 2
Based on International Radium Standard.

Date of Measurement	Activity corresponds to Mgm. of Radium Element	Activity corresponds to Mgm. $Ra Br_2$ $2H_2O$.
July 17, 1912	7.41	13.82
Oct. 25, 1912	7.85	14.65

The initial activity of this mesothorium preparation was stated by the Knofler Company of Plotzensee to be equivalent to 15 mgm. of radium bromide, which is about 10% higher than the first measurement above shows. The increase in activity of the mesothorium during the three months is in accord with the fact, that the activity of mesothorium after its preparation should increase, due to the slow formation of radiothorium and its subsequent products. According to the manufacturer's statement, the activity of this particular mesothoium preparation should reach a maximum after 3.2 years, falling to the initial activity in about 10 years.

The following table gives a list of the radium and mesothorium applicators which I have, and the measurements have all been made on the basis of the International Radium standard, at the Vienna Radium Institute.

Applicator No.	Radioactive Element	Date of Measurement	Activity corresponds to Mgm. of Radium Element
1	Radium	Oct. 25, 1912	11.04
2	Mesothorium	Oct. 25, 1912	7.85
3	Radium	June 23, 1913	14.98
4	Radium	July 10, 1913	14.88
5	Radium	July 10, 1913	15.05

The radium in applicator No. 1 was purchased in 1908 from Braunschweig as 25 mgm. of radium bromide and at that time it was fixed upon a square applicator of 2.25 sq. cm. area in the form of sulfate incorporated in a varnish, by the Armet de Lisle Company in Paris. The mesothorium applicator was obtained in 1912 from Knofler in Plotzensee, this material being enclosed in an oval *Wichman* capsule, having the dimensions; 13 mm. long. 7 mm. broad, 2.5 mm. thick with a silver cover 0.05 mm. thick. Applicators 3, 4, and 5 were obtained in finished form from the Standard Chemical Company of Pittsburgh. Applicators 3 and 4 are silver *Dominici* tubes about

*Russell and Soddy, Phil. Mag. Vol. 21, Page 130 (1911).

3 cm. long and applicator 5 is a square metal holder of 9 sq. cm. area on which the radium is fixed with varnish. The results obtained with the last three applicators are as yet few in number.

As regards the technic of application I have followed the practice of *Wickham* and *Degrais* in all details. In all superficial skin cancers the applicators were used screened only with several layers of lead foil and with 2 mm. of rubber. In larger deep seated carcinoma, the applicators were screened with from 0.5 to 2.5 mm. of lead or silver sheets. To absorb the irritating secondary rays, which may cause painful burns when long applicators are made, 20 to 40 sheets of tissue paper were put over the applicator and one or two thicknesses of muslin used as an outer covering. Lately platinum screens have been used, and these, because of their half smaller volume with an equal absorbing capacity as compared with lead screens, have proven very practicable. Wherever possible the "cross fire" method was utilized. This is accomplished by using several applicators at different points on the surface in such a way as to cause the paths of the rays to cross each other in the growth; in this way obtaining the most intense radiation effect within the tissue, with a minimum of superficial irritation.

Adrenalin injections to desensibilise the skin for X ray treatments as practised by *Reicher* and *Lenz,* are not practicable here, because of the long time of exposure used in the radium treatment.

The applicators were fastened by means of adhesive tape where the lesion was on the surface of the skin. When used in the various body cavities into which the applicators were introduced, a rubber finger cot was used to protect the valuable material, the rubber tube being tied tightly to keep out moisture, and to keep to applicator free from contamination. In the mouth cavity the applicator was fastened to a rod of aluminum bronze wire, covered with cotton, the radium or mesothorium being held in place, after having been properly arranged, by having the patient bite on the cotton covered rod. In this way an applicator could be held in place for hours. When used in the rectum, a *Foges'* rectoscope was used, by means of which it could readily be seen when the applicator was in the desired position. The applicator was then fixed in place by means of a tampon of greased gauze. In this way the applicator could be used without great inconvenience to the patient, for periods of 12 to 24 hours. To avoid irritating tenesmus a few drops of tincture of opium were finally used. In the vagina an applicator could be readily inserted in a similar manner. Two methods are available to bring the applicators into the larnyx and both of these having been utilized. Either the applicator is passed in directly on a flexible rod *per vias naturales* after cocainizing the mucus membrane, the application lasting as long as the effect of the cocaine makes it possible; or else the applicator is introduced directly into the larynx after a laryngo-fissure has been made. In applying the radium within a tumor or in artificial openings the applicator must be covered with a sterilized rubber finger cot, which is finally disinfected with tincture of iodine. For the oesophagus a bougie was used into which the mesothorium applicator could be passed.

Regarding dosage it may be said that in superficial lesions where lightly screened applicators can be used, thus utilizing the greater part of the available rays, relatively short periods of exposure are sufficient. Thus it was frequently possible to remove (without subsequent recurrence) the ordinary benign skin epithelioma of the face (epithelioma perlee of the French) in a single application lasting 50 to 60 minutes, using only a rubber covering over the applicator. In the case of the

deep seated skin cancers and particularly in deep seated nodules and infiltrations and in the treatment of carcinoma of mucus membranes the treatment is quite different. Heavy lead filters 0.5 to 2.5 mm. thick must be used, and to absorb the irritating secondary rays 20 or more thicknesses of paper must be interposed. In this case, using the thickest lead screens, only the gamma rays and a very small percentage of the hardest beta rays pass through, the "rayons ultrapenetrants "of the French. Since these rays form only a very small percentage of the total radiation it is necessary to have very powerful radioactive preparations and to apply these for a long time—days to a single exposed part. In inoperable cases experience has led me to use maximum doses. It is, however, not necessary to use such exceedingly large quantities of radium as are now being described in Germany in connection with the use of mesothorium. According to my observations a quantity of radium is sufficient for most uses, which can give a radiation dosage sufficient to destroy a carcinoma by three to four weeks of continual application, since in this relativey short period the radiation effect is cumulative. It seems to be a matter of choice, assuming that the time required for the treatment did not exceed three of four weeks, whether the effect is attained by means of a cumulative equivalent radiation dose using smaller but nevertheless rather considerable quantities of radium or mesothorium during correspondingly longer periods of exposure, or whether several hundred milligrams of radioactive material are used for correspondingly shorter intervals, as *Kronig* does for example. In general, according to my experiences, several applicators each containing about 15 mgm. of radium element are sufficient to treat a case, if these are used continually day and night till the desired radiation dose is attained. For certain purposes, as for example in the treatment of cancer of the mouth, pharynx and larynx where longer exposures can only be made with the greatest difficulty, it is a great advantage to possess considerably more powerful applicators. So if only a small quantity of radium is available, the applicator must be used continuously for weeks on a single case and of course the position of the applicator must be varied in a suitable manner.

In a case of an inoperable recurrent carcinoma of the cheek and the mucous membrane of the palate, which will be cited later, a single treatment lasting 31 days was given which equalled 7,200 mgm. hours. (Ra. element). To my knowledge no such dose has ever been given before.

With reference to the expression "milligram hours" which is frequently used now, it may be said that this is strictly incorrect as a measurement of dose viewed from a purely physical standpoint. It is obvious that it makes a great difference whether the same quantity of radium is spread over a small area or over a much larger area and the extent to which an apparatus is screened makes a tremendous difference in the results. With the same applicator applied for the same interval (that is the same number of "milligram hours") very different results will be obtained when the instrument is used with little screening, so that the greater part of the available radiation is effective, as compared with the results obtained using a heavy lead screen which absorbs all but the hard gamma rays. Furthermore, there will be a great difference depending on whether the applicator is applied on the surface of a tumor so that only the rays are utilized which pass in the direction of the tumor, or whether the same applicator is in-

serted in the tumor mass, thereby utilizing the radiations that pass in all directions. The term "milligram hours" will only serve as an approximate measure of dose if it is restricted to strongly screened applicators where only the gamma rays are effective; and particularly to apparatus in which the area over which the radium is spread is small (e. g. tubes and small applicators). Further the term "milligram hours" should not refer to any salt (bromide, sulfate, etc.) but rather to the activity of the applicator expressed in terms of milligrams of radium element, on the basis of the new International Standard.

In concluding this discussion* of the matter of dosage a few remarks may be made concerning certain idiosyncrasies towards radium rays. The sensibility of the skin to the radium rays varies within certain limits with the individual. Children are much more sensitive than adults, and old people often stand surprisingly large doses without noticeable reaction. People with a delicate skin, particularly women of delicate complexion show in general a greater sensitiveness to the radium rays. Even the different portions of the skin of an individual shows different degrees of sensibility, but this sensibility varies, if the dosage is taken into consideration, within such limits, that it is not in general possible to speak of a true local idiosyncrasy. At least in the several thousands separate radiation treatments which I have carried out, I have not as yet been able to observe a single undoubted case of local idiosyncrasy. It cannot, however, be said that such an idiosyncrasy could not occur. The tissues become hypersensitive through previous radiation treatment. If the tissue has been treated even months before, subsequent treatment produces a much more vigorous reaction than the same treatment would produce on an untreated place. This point must be carefully considered. This circumstance often leads to difficulties in the treatment of recurrences in tissues affected by previous raying. In such cases the result may be much the same destructive action that is observed in the case of tumor cells. If the treatment is made with smaller dosage, the cancer cells are not sufficiently affected and if the treatment is intensive enough to affect the cancer cells, there is the danger of causing necrosis of the surrounding healthy tissue, which has become sensitive because of previous treatment. It is often a matter of difficulty to attain the proper dosage in such cases.

SYMPTOMATOLOGY OF RADIATION TREATMENT

The rays of radium like the X ray, do not cause any pain or sensation during the period of exposure. The tissue may be badly injured, although the patient feels nothing of it while being "burned." Even shortly after the raying there is no objective change to be observed in the part that has been treated. The reaction which occurs (as *Wickham* and *Degrais* say, the answer to the disturbance which the passage of the radioactive energy causes) will differ depending on whether no screen or thin screens or heavy metal screens covered with paper are used. In the former case, after a suitable exposure (a few minutes to an hour) an inflammatory reaction takes place, a sharply

*A quotation is given from *Wickham*, and *Degrais* whose work has laid the foundations of modern radium therapy and whose authority in this field is recognized. "It may be said once for all, that it is impossible to use radium without being confident in all the details and indications which the various methods and technics necessitate, and this confidence is only to be gained by long experience. If all cases that come under consideration are treated with large quantities of radium without using judicious discrimination, if the suitable dose and screening for each case is not given careful consideration, bad results will be obtained, burns will result and the method will be discredited. In brief, radium is a fine and delicate therapeutic agent and its use necessitates the most skillful handling by a clinician having wide experience in Radium Therapy." (*Lazarus* Handbuch der Radium-Biologie und Therapie, Page 403).

defined erythema occurs on the spot treated after a latent period of from several hours to three weeks. (1st degree reaction) If the dose has been low, the resulting erythema slowly disappears in the course of several weeks, scaling of the skin sometimes occurring. If the dose is stronger, the erythema will be followed by the formation of a crust. (2nd degree reaction) The crust falls off in from two to six weeks, re-forms several times, the successive crusts being thinner, the radium dermatitis finally disappears leaving a somewhat depigmented spot, soft, and not like a scar, If the raying was more intense, a superficial or even a deep necrosis of the tissue results which requires many weeks to heal. (3rd degree reaction) Different statements with regard to the length of the latent period are to be found in the literature, being given as from a few hours to four weeks. In general it is found that the latent period, that is, the interval elapsing between the raying and the first visible reddening, is inversely proportional to the applied radiation dose. (cf. *Sticker*, in *Lowenthal's* Handbuch der Radium Therapie) This is true up to a certain point, but the early appearance of the reaction depends upon whether wholly unfiltered applicators which give off the soft rays are used or whether screens are used. With varnish applicators where a part of the alpha rays may pass through the varnish, a primary erythema may result in several hours. Even if thick metal filters are used, if the secondary rays are not sufficiently absorbed a faint redness may often be noticed at the spot treated, after a day. The reaction caused by the harder rays usually only occurs after two or three weeks. Usually in the case of prolonged rayings the main reaction follows gradually upon the primary erythema, where this does occur, so that a gradually increasing erythema or an erythema with crust formation is observed. The early or late occurrence of the reaction will also depend upon the dosage—as has been said before. A consideration of these varying relations makes it possible to explain satisfactorily the variations in the reported latent periods. If a suitable thick lead screen has been used, and the secondary rays have been absorbed by interposing layers of paper, very large doses may be given without irritating the surface. In the case of maximum doses applied for penetrating raying, an erythema or superficial dermatitis must be expected. However, this dermatitis soon heals without causing further damage. Sometimes when using maximum doses for penetrating effects, a rather far reaching edema results which may be some time in disappearing. After placing radium into an operative opening a somewhat protrated course was observed in the wound.

The effects of the radium rays upon carcinoma vary depending on the sort of carcinoma and upon the sort of radiation treatment. As regards the first point it must be emphasized that the carcinoma tissue shows less resistance to the destructive action of the radium rays than does normal tissue; so that there is a selective effect exerted by the radium rays on the carcinoma tissue. The radiosensibility of various cases may differ and in a fashion that cannot be foretold *a priori*, though often soft tumors rich in cells are found to be very sensitive to raying. While some cases react promptly to the raying, others are less easily influenced, and a small percentage have proved refractory with the dosages so far used.

The effect on the carcinoma tissue will also depend upon the method of raying. If little or no filtering is used, so that there are soft beta and sometimes even alpha rays along with the harder rays, then there results as has been said, a vigorous reaction leading to superficial or even deeper necrosis of the carcinoma tissue. The rays in the main are

acting as a sort of local caustic. It is these violent undesirable reactions which make this method undesirable in most cases. It is because in this method the most irritating rays, which also form the greater part of the total radiations, are effective and unless applied for only a short time, cause bad burns. The effect is mainly superficial since in the time of application the proportionally fewer penetrating rays cannot have an effect deeper in the tissue. So this method is only applicable in cases of superficial skin cancers where in the short time of application the penetrating rays do not have a chance to cause any considerable effect. For other cases large doses using heavy screens is the method of choice. This sort of treatment results in less violent effects since here only the very penetrating gamma rays, freed from the secondary rays, come into play, thus obtaining an intense deep seated effect in utilizing the selective effect of the radium rays on the carcinoma tissue. However, it must be observed that the dose is sufficient to retard the growth of the cancer cells in the deepest and most remote parts of the neoplasm. Otherwise there is a destruction of the nearlying tumor mass, but as the intensity of the rays diminishes proportionally to the square of the distance, finally only a stimulating dose reaches the youngest tumor cells and this simply stimulates these cells to more rapid proliferation, as I have been able to plainly observe in a case of colon carcinoma. Therefore, to avoid this danger, not only must maximum doses be applied, but the whole affected part must be thoroughly rayed. It is well to even place a tube applicator within the tumor mass.

Objectively, the results of the raying are as follows: The cancerous lesions begin to clear up, often after the disintegration of necrotic tumor material, the putrid secretion diminishes and loses its fetid character, hemorrhage ceases, hard infiltrated margins break down and the loss of substance which results is finally covered with skin from the margin. This process may also take the form of a simple softening and resorportion of the tumor mass without any necrosis of the tissue. Hard carcinomatous infiltrations become soft, of the consistency of normal tissue, after first showing a temporary reaction edema or swelling due to the raying. Subcutaneous nodules and gland tumors disappear leaving small indurations apparently of connective tissue. It must be emphasized that metastases of the glands often show a great resistance to radium treatment. *Werner* distinguishes three reaction forms of tumors towards Roentgen rays; 1st, shrinking into connective tissue; 2nd, colliquation; 3rd, necrosis. While I have often observed the 1st and 3rd reactions after radium applications, only in one case have observed a partial colliquation, that is a liquifaction of the tumor, this occurring in a case of colon carcinoma treated by placing a mesothorium capsule within the tumor itself.

Subjectively, the influence of radium application makes itself known by a diminution of the pain. This analgetic effect is very important and especially to be emphasized because as is well known the pains caused by carcinoma are of the most painful nature and often are not to be relieved by the use of the highest doses of narcotics. Radium is valuable in inproving the subjective condition even in quite hopeless cases, where there is no prospect of prolonging life or of affecting the cancerous growth, since it lessens the pain or even causes it to cease. As an example of such a case I will mention a later cited case of primary endothelioma of the pleura.

In the rapid softening of large tumors as a result of intensive raying toxemic conditions often result, patients showing a fever up to 39.5° C, and a high degree of exhaustion and fatigue, often even when the height of the fever is not sufficient to explain the latter condition. Nausea and vomiting are often associated as symptoms, which point to a severe toxemia in the organism due to the resorption of decomposition products. I could often notice a direct parallelism between the height of the fever and the extent of the radiation dose. Great care must be taken in regard to this toxemia in the treating of large tumors, since it may stand in the way of using an intensive raying which would otherwise be desirable.

Corresponding to the local improvement of condition there is also a general improvement, the patient regains his appetite, the body weight increases appreciably and the cachexia disappears. Even in cases where the objective improvement is not very pronounced, the favorable influence of the raying on the general condition is to be observed.

Histologically the influence of the radium rays on carcinoma tissue as *Exner* first observed is a necrobiosis of the tumor cells with vacuolization and finally a disappearance of these cells together with the appearance of a sclerotic connective tissue which tears the cancer cells apart and breaks them into small groups, where they eventually are destroyed.

In addition to the above mentioned toxemia which may result from the radium treatment of large tumors, the following phenomena must also be considered: 1st, burns, undesirably intense reactions leading to necrosis of tissue; 2nd, hemorrhages due to erosion of the blood vessels; 3rd, perforation of hollow organs. With respect to the first it may be said that suitable dosage and screening can only be learned by long experience with each particular applicator. This experience will enable one to keep the damage to the skin and mucous surfaces within such limits, that the resulting reaction soon passes without further bad effects. Erythema and superficial crust formation on the skin have no serious significance and soon heal not being at all comparable, as was first thought, to the severe X ray burns. The more undesirable deeper necrotic effect upon tissues may be avoided by using suitable screens and carefully controlled doses. As regards the hemorrhages which various writers have observed after very intense raying, I wish to state that I have never observed any such effects, not even in two cases where the applicators were in attached quite near to the large cervical vessel for twenty-four hours. In all about 500 milligram hours were applied to the vessel wall without harm resulting. However, I took care to enclose the applicator in two mm. of lead and covered this with suitable thickness of rubber tissue to absorb the irritating secondary rays. With insufficient screening for the absorption of the secondary rays, it is quite possible that a direct necrosis of the vessel wall may lead to bad hemorrhages. This undesirable result may even be avoided in the case of carcinomatous infiltrations of the vessel wall itself, by a suitably selected dosage and sufficient screening. If this condition of a vessel is suspected the greatest care must be used, preventive ligature of the threatened vessel being necessary. As to perforation of hollow organs. I have only seen one such perforation in an osephagus carcinoma (together with Dr. H. *Marschik*). Still in this case, because of the whole clinical course and because of the small radiation doses used (30 milligram hours of mesothorium screened with 1 mm. silver

and a suitable thickness or rubber), it is probable that the perforation was not due to the raying, since it formed after the second one hour application, and it is likely that it would have occurred in any event. In another case later cited (H. St., carcinoma of the mucus membrane of the cheek) by an accident the rubber covering was torn, and so the irritating secondary rays came into play. These acting on a spot sensibilized by previous large doses, led to a perforation in the cheek, about the size of a dime. Except for the unfortunate fault in screening which was due to poor manipulation by the patient to whom the applicator had to be entrusted, it is probable that the perforation would not have occurred, even with the high doses applied, and this illustrates the importance of cutting off the irritating secondary rays. It is necessary to work very carefully on the case of infiltrations in the walls of the hollow organs (stomach, intestines, bladder, oesophagus, etc.) where the accelerated disintegration of tumor masses may lead to perforations that may result fatally. By suitable screening and dosage the dangers can be reduced to a minimum. Although I have applied doses of thousands of "milligram hours" in cases of carcinoma of the colon and rectum, I have never had any such accident occur.

(To be concluded in the next number)

NOTES AND COMMENTS

The Bureau of Standards at Washington, D. C., has recently secured several radium preparations from the Standard Chemical Company of Pittsburgh, Pa., which will be calibrated for use as radium standards. Heretofore the Bureau has not been in a position to make measurements of quantities of radium, but we are informed that it is expected that in the near future this work will be carried out; and the acquisition of radium for the Bureau's standards marks a step in this direction.

* * * * *

A very interesting display of radium salts and pharmaceutic radium preparations was exhibited by the Radium Chemical Company of Pittsburgh during the Annual Meeting of the Medical Society of the State of Pennsylvania, at Horticultural Hall, Philadelphia, September 22nd to 25th, 1913. The display consisted of radium salts (over a hundred milligrams of radium element being shown in the form of salts mounted in various forms of applicators), radium solutions for injection, radium drinking water, radium bath water, radium, compresses and radioactive earth. These are all products of the Standard Chemical Company of Pittsburgh, which produces its radium from Colorado carnotite ores. In addition to the radium preparations, an Emanator built by the Standard Chemical Company was displayed. This apparatus is used in the preparation of radium emanation drinking water, and for charging air with emanation for inhalation. Various forms of instruments used in the application of radium for the treatment of cancer and other diseases, were also shown, and demonstrations were made of the methods of measurement of radium.

* * * * *

The Report for 1912 of Director *Jungmann* of the Lupus Institute in Vienna, shows the very favorable results obtained in the treatment of lupus with the radium rays. While surgical treatment in suitable cases is still considered the method of choice, radium comes next as the best method of actinic treatment. Of the patients treated, 561

were treated surgically and cured; 605 were treated by Finsen light, 935 by X-rays and 610 by radium.

* * * * *

Dr. William H. *Cameron* of Pittsburgh, Pa., presented a paper to the Medical Society of the State of Pennsylvania, on "Mechanical and Physical Agents." at the annual meteing of the Society in Philadelphia, September 24th, 1913. In this paper Dr. *Cameron* gave an account of his work with radium and radium and radium emanation in the experimental clinic of the Standard Chemical Company, at Pittsburgh, and in his private practice, and he stated it as his opinion that radium is the most valuable physical agent that Medicine possesses.

* * * * *

Madame *Curie* has been engaged in founding a Radium Institute at Warsaw, Poland, during the past summer, but will, according to a note in Science, return to her position at the Sorbonne in Paris this fall.

* * * * *

As a result of the success in the application of radium in the treatment of malignant tumors, and particularly in the treatment of cancer of the uterus, there has been a general movement on the part of the larger German cities, including Berlin, Frankfurt, Munich, Essen, Mannheim, Hannover and Duisburg, to secure larger quantities of this valuable material for use in the municipal hospitals at these places. The market supply of radium produced in Europe has been exhausted and Germany now returns to America for supplies of radium.

* * * * *

Professor Karl *von Noorden*, has given up his position as director of the First Medical Clinic of the University of Vienna, and will return to Frankfurt. Professor *von Noorden's* work is world famous, some of his more recent work being on the applications of radioactive substances in internal medicine. Considerable difficulty is being experienced by the authorities in finding a successor to Dr. *von Noorden*, Professor *His*, of Berlin, also well known by his work on radium emanation therapy, being the latest to refuse the Vienna position.

* * * * *

At the Seventeenth International Medical Congress which met in London, August 6th to 12th, 1913, the application of radium was much discussed in the section of Obstetrics and Gynecology, of Dermatology and of Radiology. Dr. Foveau de *Courmelles* of Paris gave a very favorable report of the use of radium and X-rays in malignant diseases. Of 100 cases of inoperable carcinoma, improvement was obtained in 70 for from one to four years. Professor *Doderlein* was very enthusiatic in his support of the claims of radium and mesothorium, and Professor *Jacobs* of Brussels, preferred radium to radical operation in extensive malignant cases. The discussion as a whole was very favorable to nonoperative treatment, but the dangers of possible degeneration, developing malignancy and sterilization were pointed out fully. In the section on Dermatology, Mr. A. E. H. *Pinch*, Director of the Radium Institute, London, opened the discussion on the use of radium in skin diseases, and he stated that radium is the best agent for the treatment of many diseases such as rodent ulcer, warts, eczema and for moles and vascular nevi and keloid radium treatment gives splendid results and psoriasis while later recurring—responded to very short applications. There results fully confirmed by the French works, including the pioneers in the radium application; Drs. *Wickham* and *Degrais*.

II. Radio-Active Matter In The Atmosphere.

By W. W. Strong, Ph. D.
Mellon Institute of Industrial Research, University of Pittsburgh.

In the year 1901, *Geitel* and C. T. R. *Wilson*, working independently of each other, showed that air is not a perfect insulator. Many of the greatest physicists had held the view that dust free air is a perfect non-conductor, but *Geitel* and *Wilson* proved conclusively that ordinary air is slightly ionized. This ionization of the air varies in intensity from place to place and from time to time and it was to explain some of these remarkable variations that *Elster* and *Geitel* proposed the hypothesis that this ionization was due to radioactive products in the air. Experiments carried out by many investigators all over the world indicate that this hypothesis is correct.

The study of the ionization of the air has resulted in the discovery of two more gaseous constituents of the atmosphere, radium emanation and thorium emanation. These emanations disintegrate into the solids, the radium and thorium active deposits. These active deposits thus form a virtual "radioactive dust" in the air, a "dust" that plays a much more important role than would be expected of such a minute quantity of matter.

THE RADIOACTIVE DUST IN THE AIR.

The early investigators thought that new radioactive substances might be discovered in the air, but up to the present time only radium and thorium products have been detected with certainty. The usual method of collecting "radioactive dust" consists in exposing a negatively charged wire (several hundred or thousand volts) to the air and then studying the activity of the deposit. This activity is found to behave in every way like a mixture of the radium and thorium active deposits, the relative amount of radium and thorium depending upon the locality. By making exposures of the charged wire for twenty or thirty hours one obtains equilibrium quantities of the radium and thorium deposits. For such a "maximum deposit" *Bumstead* found 30 per cent. to be due to thorium (New Haven); *Blanc* 70 per cent. (Rome); *Wilson* 60 per cent. (Manchester, England) and S. J. *Allen*, 60 per cent. (Pittsburgh). The amount of "radioactive dust" is usually greatest in stagnant air such as is found in rooms, cellars and caves. According to *Elster* and *Geitel*, greater quantities are to be found when the temperature and barometric pressure are low. It is washed from the air by rains and snows, thus making rain water and snow slightly radioactive. Through the great cyclones, anticyclones and other air currents of our atmosphere the "radioactive dust" becomes very widely diffused. Comparatively large quantities of the dust have been observed at altitudes of 15,000 and 20,000 feet, and at sea for distances of a thousand miles or more from land. As seen from the following table its intensity seems about as great over the Arctic regions as it is in the warmer regions of the earth's surface.

		Activity		
Observer	Locality	Mean	Maximum	Minimum
Elster and *Geitel*.	Germany.	19	64	4
A. *Gockel*.	Switzerland.	84	170	10
Simpson.	Norway.	93	432	20
Simpson and *Wright*	Indian Ocean.	6	21	1
Simpson and *Wright*	Australia.	124	...	..

The negative ions and dust particles of the air probably collect the "radioactive dust" in much the same way as a charged wire. In Pittsburgh the radioactive dust is probably gathered by the smoke and much of it falls with the soot. All exposed surfaces thus become coated with a thin deposit of this "radioactive dust" so that the air is ionized to a greater extent near the ground and near the surfaces of plants than it is at greater altitudes. Whether this ionization aids the growth of plants or has any effect upon living matter is still an open question. The fact that the air is ionized has a very considerable effect upon the potential gradient of the air and it is quite possible that the existence of this gradient, averaging about 100 volts for each increase of 3 feet in altitude above the ground, does influence life processes. The emanations and the "radioactive dust" also cause the formation of small amounts of ozone, hydrogen peroxide and oxides of nitrogen.

THE RADIOACTIVE GASES IN THE ATMOSPHERE.

The electrical condition of the air, the existence of thunder-storms and of various kinds of lightning, the aurora and many magnetic effects are due to the radioactive gases and "radioactive dust" in the air, to dust storms, to the splashing and breaking of water surfaces, to ultra-violet light and possibly to penetrating radiations coming from the voids of interstellar space. Probably by far the most important element affecting the electrical state of the atmosphere is that due to the radioactive gases and dust. The formation and breaking of water surfaces may be important for a short time during a rain but the effect of radioactive matter is going on ceaselessly—during the night as well as during the day, in summer and in winter. Probably a large percentage of the ions in the air are formed by the alpha, beta and gamma rays from these products and the only way that the air can conduct electricity is by the motion of these ions. As the air is usually positively charged with reference to the earth, it follows that there is a current of electricity flowing down through the air into the ground. This current has been frequently measured.

Several painstaking researches have been made to determine the amount of radium emanation in the air. *Eve* at Montreal and *Satterly* at Cambridge (England) have caused known volumes of air to pass through charcoal. The cold charcoal absorbed the radium emanation and on heating, the quantity of radium emanation given off is measured. Radium emanation is condensed on being cooled to liquid air temperatures and *Ashman* (Chicago) has used this method of separating the emanation from known volumes of air. The average content of radium emanation in the air as measured by these investigators is given in terms of the amount of pure radium that would have to exist in a cubic meter of air in order to give the equilibrium quantity of emanation existing there.

Eve	60×10^{-12} gm. radium per cu. m.
Satterly	100×10^{-12} gm. radium per cu. m.
Ashman	89×10^{-12} gm. radium per cu. m.

This means that every cubic centimeter of air would require about 400,000 radium atoms to generate the amount of radium emanation that is being transformed into radio-active dust. This would mean that from 6 to 8 alpha particles are produced per cubic meter of air per second and these would generate about 2 ions per cubic centimeter of air per second. The beta and gamma rays would also generate ions. The number of ions produced per cubic centimeter per second has been

found to be somewhat larger than this value so that it is not yet certain whether all the ions in the air are produced by the radioactive gases and dust or not. Experiments like those of C. T. R. *Wilson* on the tracks of alpha and beta rays should throw light on this problem.

If it is assumed that the radium emanation has a density corresponding to the equilibrium value of 80 x 10^{-12} grams of radium and that it extends to a height of 10 kilometers about one gram of radium would be required for each square kilometer of the earth's surface to give off the above amount emanation.

THE IONS OF THE AIR.

We have seen that the radio-active gases and dust generate ions in the air. What becomes of these ions? The answer is that they may combine with water dust or other small solid particles and thus form "large" or "*Langevin*" ions or the positive and negative ions may neutralize each other's charge by recombining. Near the ground and in the region of large cities there are very large numbers of "*Langevin*" ions, thousands of them per cubic centimeter of the air. In the pure air of the mountains and over the sea there are compartively few dust particles and large ions. The ions are then "small" or "intermediate" in size and number a few hundred per cubic centimeter. "Small" ions are of the same order of size as the oxygen and nitrogen molecules, whereas the so-called "intermediate" ions are hundreds of times as large. The *Langevin* ions are do large that they can either be seen by the eye or by the microscope. In the upper layers of the atmosphere—where the aurora discharges take place, the ions are probably all "small" ions or electrons.

Up to the present time very little accurate work has been done upon the ionization of the air. The work of *Elster*, *Geitel*, *Gockel* and the German School has brought to light a large amount of important and interesting data on the rate of discharge of charged insulated bodies in the air, on the potential gradient and upon the number and rate of recombination of ions in the air, but the condions under which the experiments were carried on are so complex that the answer to many of the riddles of atmospheric electricity has not been given. The weather bureaus of the various nations should take up this problem.

In the section discussing the cosmical effects of radio-active matter, further references will be made to the ionization of the air.

THE RADIUM AND THORIUM IN THE ROCKS AND SOILS.

Among the first to make a quantitative determination of the amount of radium in the soils was R. J. *Strutt*. Small quantities of radium were found in practically every kind of rock tested. The rocks formed by igneous processes gave an average radium content of 1.7 x 10^{-12} gm. of radium per gm. of rock, the values ranging between 0.3 and 4.8 x 10^{-12} gm. The sedimentary rocks were found to possess a smaller radium content than the igneous rocks. Since then, *Eve*, *Joly* and many others have continued this work. In general, the disintegrated rocks, such as the ordinary soils, are found to be poorer in radium than the unweathered rocks. Weathering thus removes a considerable part of the uranium and the radium.

Blanc, *Joly* and others have found thorium to be present in minute quantities in practically all rocks and soils investigated. In some rocks *Blanc* found a thorium content so great that it would emit six

times as intense a gamma radiation as the uranium and radium combined. *Joly* obtained an average content of about 1×10^{-5} gms. of thorium per gm. of rock, for 19 various rocks. A series of calcareous and dolomitic rocks gave only 0.07×10^{-5} gms.; the St. Gothard tunnel rocks 1.13×10^{-5} gms. (the uranium content being 1.46×10^{-5} gms.); the Trans-andine rocks 0.56×10^{-5} gms. and Leinster granite 0.7×10^{-5} gms.

This comparatively small number of analyses show that radium, thorium and uranium are distributed throughout all the rocks and soils. As the study of radium promises to tell a great deal about the processes of diffusion of small quantities of matter through the body, so a study of the rocks and soils promises to tell much concerning the processes that are involved in geological changes. The uranium and thorium products emit alpha particles in the rocks just as they do in the laboratory and the alpha particles possess a characteristic range (or distance they penetrate before being stopped) in a given rock just as they do in air. Thus a little uranium or radium in a glassy like rock will be surrounded by a spherical portion of discolored material. These spherical portions of rocks are known as pleochroic halos. The cause of these haloes was a mystery before the discovery by *Joly* that there was a small quantity of radioactive matter at their center.

THE RADIUM AND THORIUM IN THE OCEAN.

The amount of radium in sea water is much smaller than that in the rocks, being on the average only about a thousandth part as great. *Eve* found about 0.9×10^{-15} gms. of radium per gm. of sea water while *Joly* obtains higher values.

The thorium and uranium content of the ocean and its sediments is one of the most important factors concerning the problem of the radioactive deundation of the continents. From the work of *Joly* it seems altogether possible that the radium of the surface waters of the ocean is removed through precipitation by the action of decaying organic life. Notwithstanding the small radium content of the ocean water, *Joly* estimates that there is 20,000 tons of radium in the oceans.

The small radium content of the ocean water seems to be balanced by a large quantity of radium spread over the ocean floor. It is probable that in the main the continents and the big ocean bottoms have been very permanent parts of the earth's surface and that radium has been accumulating in the red clay, the globigerina, the radiolarian and the diatom oozes at the bottom of the oceans. The extraction of the lime salts does not seem to carry the uranium down, however. *Joly* and others believe that uranium remains in solution in the oceans and that the radium present in the water is generated there by the uranium. One argument in favor of this view is the fact that it takes about 50,000 years for the rivers to carry enough of water to fill the oceans while the period of radium is only about 2,000 years. Then again rain water contains a very low radium content. The rivers therefore, seem to carry uranium to the ocean and the radium is generated there in situ.

It is well known that mountain building takes place mostly near the coasts of the continents where sediments are being laid. It is also known that volcanic action seems to fringe the oceans with a line of volcanoes. Several geologists have put forth the hypothesis that volcanic heat is generated by local rich radioactive deposits and that the whole process of mountain building and of volcanic action is intimately related with the concentration of radioactive matter through the weathering and erosion of the continents.

THE PENETRATING RADIATION.

Almost simultaneously in 1902, *Rutherford* and *Cooke*, working at McGill University and *McClennan* and *Burton* working at Toronto University, announced the discovery of the existence of a penetrating radiation, a radiation much like the gamma rays of radium, that seems to exist everywhere over the land. This radiation is so penetrating that a considerable portion of it is transmitted by lead screens several centimeters in thickness. The intensity of the penetrating radiation varies at any one place and it seems to show a double diurnal period, there being two maxima and two minima every twenty-four hours. There is a great deal of discrepancy among the various observers concerning the amplitude and the time of these periods.

Wulf has studied the intensity of the penetrating radiation in various parts of Germany and France, including measurements made on the top of the Eiffel Tower. In his work the intensity of the penetrating radiation is measured in terms of the number of ions (q) which it will generate in a cubic centimeter of air per second. The following table shows how the intensity of the penetrating radiation may vary inside of buildings, due largely to the kind of material in the walls.

Place	Material of the Walls.	Age (years).	q
Abbey of Maria-Laach, near Audernach-sur-Rhine.....	Volcanic tufa	50	13.7
Fauquemont, College.......	Brick	15	5.7
Louvain, College	Brick	30	8.0
Namur, College............	Brick	100	3.7
Wijnandsrade, Chateau.....	Brick	210	0.0

The work of *Gockel, Wulf, Hess, Pacini,* and others, indicate that at high altitudes, even to heights of 10,000 feet or more above the ground, the intensity of the penetrating radiation is as great as it is near the surface of the ground. On the other hand, it appears from the work of *McClennan, Wright, Simpson* and others that the penetrating radiation is very weak over the ocean and the larger lakes.

The penetrating radiation was predicted in that it was known that the ground and the air contained radioactive products. But how much of the penetrating radiation comes from the ground and how much from the air? The writer suggested that the part showing a diurnal variation probably came from radioactive products in the air or the active deposit resulting from the decay of these products, whereas the more constant portion came from the radium and thorium in the ground. As the intensity of the radiation shows quite a large diurnal range it was argued that a considerable part of the radiation came from radium emanation, A, B and C in the air, or deposited on the surfaces of buildings, etc. The quantitative measurements of the amount of radium emanation in the air indicate that it would require about twenty times as much radioactive matter in the air as was obtained by *Eve, Satterly* and *Ashman* to give the value of q as obtained by *Hess* in his balloon experiment. So at the present time it may be said that the penetrating radiation is very much stronger and extends to much higher altitudes than would be expected from the amount of radium and thorium products in the ground and in the air.

Although it does not seem to have been tried it is possible that the penetrating radiation might serve as a means of detecting rocks with a high radium or thorium content. It is known that potassium and rubidium emit beta rays. Whether gamma rays are emitted or not by these elements is at present unknown. If these elements do emit gamma rays, then regions where there are large potash deposits should show an intense penetrating radiation.

Is there a penetrating radiation in space? Do the stars, the sun, the moon etc. emit a penetrating radiation? It is quite probable that they do—expecially those bodies such as the moon, that possess little if any, atmosphere. It is doubtful however, if any such radiation can penetrate our atmosphere, it being equivalent in absorbing power to 30 cms. of mercury. If the radiation was more highly penetrating it could easily pass through our atmosphere. Up to the present time no evidence of any cosmical penetrating radiationh as been obtained.

If it were possible to focus the gamma radiation and to transmit parallel beams of it, and if radium was not so expensive, it might be used as a means of signalling. Imagine a prisoner in a cell with a small quantity of radium. He moves this back and forth in front of his window so that at one time the gamma rays are cut off by the wall while at other times the rays pass on to the outside. His motion is made to correspond to the dots and dashes of a *Morse* telegraph code. A man at a distance has an ionization chamber connected to a galvanometer and the galvanometer needle records the dots and dashes. This constitutes probably the simplest possible form of wireless apparatus.

Another question, do the radium and thorium emanations in the air, the active deposit or the penetrating radiation either directly or indirectly affect our health? Does it affect the growth of plants? At the present time no definite answer can be given but the writer has thought that such effects existed, especially as regards the growth of plants. The existence of the emanations and of the active deposit certainly affects the ionization of the air very greatly in the neighborhood of plants and this affects the potential gradient. The potential gradient should have a very pronounced influence upon the flow of the sap.

In the early days of radioactivity it was suggested that there was either a penetrating radiation or a kind of pervading energy that the disintegrating radioactive atoms could transmute into kinetic energy. It may be that there is a penetrating radiation coming from space that penetrates the upper 10 or 20 kilometers of the earth's surface and causes the thorium and uranium radioactivity. The generally accepted belief today is that the cause of radioactivity depends upon the structure of the atom itself. The quantitative relations between the atomic constants, the decay constant and the initial velocity of the alpha particles of the different radioactive elements supports the latter view. *Swinne* finds that the difference between the initial velocity of an alpha radiator of one family and the corresponding element of another family is nearly a constant. On the other hand, it may be these properties of certain atoms that gives them the power of absorbing outside energy. If there is such a very penetrating radiation and its intensity showed periods of maxima and minima, the amount of heat generated by radioactive processes would fluctuate. These fluctuations might aid in the explanation of the glacial epochs.